MeSMarT – Measurements of Shipping Emissions in the Marine Troposphere

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1. Motivation

Shipping emissions:

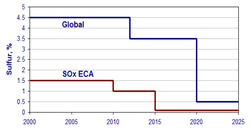
- Pollution components: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOCs), black carbon (BC), polycyclic aromatic hydrocarbons (PAH), particulate matter (PM)
- Impact on marine tropospheric chemistry, ecological and climatic effects (formation of ozone and aerosols, acidification, albedo)

- Strong health endangerment of people living in harbour cities and coastal regions
- Especially dangerous with combustion of heavy oil fuels, with high sulfur content and strong soot emission

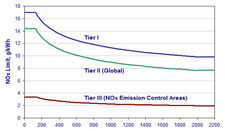
Political Measures:

- Convention of the International Marine Organization (IMO) for Prevention of Marine Pollution from Ships (MARPOL 73/78 Annex VI)
- Limitation of sulfur content in heavy oil fuels in Sulfur Emission Controlled Areas (SECA)
- Establishment of general Emission Controlled Areas (ECA)
- Regulation of NO_x emissions from newly built marine engines

ECA zones around the world



Reduction of sulfur content in heavy oil fuel within SECA zones and globally as determined by MARPOL Annex VI



Limitation of NO_x emission by engines, built after 2000 (Tier I), 2011 (Tier II), and 2016 (Tier III)

2. Objectives

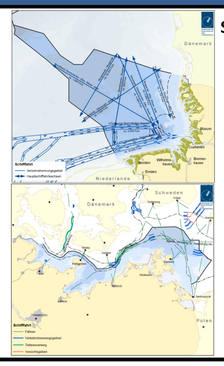
MeSMarT – a cooperation between University Bremen, Federal Maritime and Hydrographic Agency, and Helmholtz Zentrum Geesthacht

- Assessment of different measurement systems such as remote sensing, in-situ, and passive sampling measurements as methods for long-term monitoring of shipping emissions in the North and Baltic Sea
- Improvement of ship emission data bases by measurements of the actual distribution of trace gases and aerosols related to ship emission
- Validation of satellite measurements and model data
- Description of the influence of ship emissions and its secondary products on the marine environment
- Development of a concept for controlling ship emissions

3. Operational area and Platforms

German Bight and Baltic Sea:

- German Exclusive Economic Zone, with 12-nm-zone und main shipping routes
- An area already covered with extensive research concerning water quality and oceanography by BSH



Ships (routinely used by BSH):

RV Celtic Explorer

RV Atair

RV Pelagia

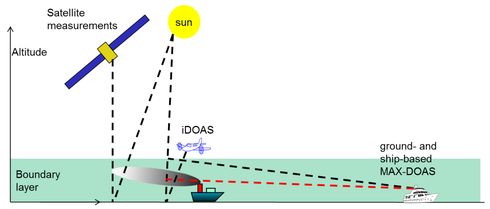
Stationary Platform:

- Neuwerk – a remote location but close to main shipping routes and with good accessibility
- Instruments will be installed on the radar tower
- In cooperation with WSA (Wasser- und Schifffahrtsamt Cuxhaven)

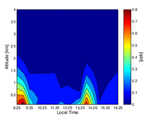
4. Measurement techniques and modelling

Remote Sensing for NO_2 and SO_2 from different platforms

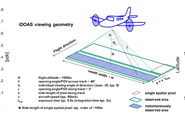
- Retrievals based on Differential Optical Absorption Spectroscopy (DOAS)
- Measuring spectra of scattered sunlight (therefore results only during daytime)
- Deriving trace gas columns and profiles from absorption features considering the radiative transfer in the atmosphere (RTM SCIATRAN)
- Techniques combine good spatial coverage (satellite), high spatial resolution (iDOAS) and high sensitivity (detection limit 50 ppt for NO_2) plus profile information (MAX-DOAS)

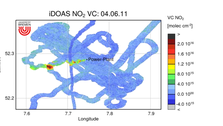


From ground/ship: MAX-DOAS

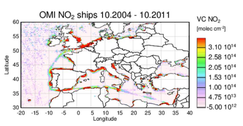


Airborne: iDOAS





From space: Satellite DOAS



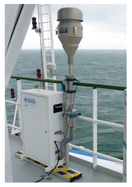
In-situ measurements:

- Airpointer from MLU

	SO_2	NO, NO_2, NO_x	O_3	CO_2
Measuring principle	UV-fluorescence (EN 14212)	Chemiluminescence of NO (EN 14211)	UV-absorption (EN 14625)	Non-dispersive IR-spectroscopy LI-COR LI820
Detection limit	0.25 ppb	0.4 ppb	0.5 ppb	1 ppm
Measuring range	< 10 ppm	< 20ppm	< 200 ppm	< 20000 ppm
Time period	< 90 s	< 60 s	< 30 s	1 s

Filter sampling:

- Digitel High Volume sampler DHM 60
- Inlet with PM10 pre-separation
- Flow: 6-60 m^3/h
- Filter: Ø 150 mm quartz or cellulose filter
- collection time: 8 – 24 h



Filter analysis:
(has yet to be tested and established)

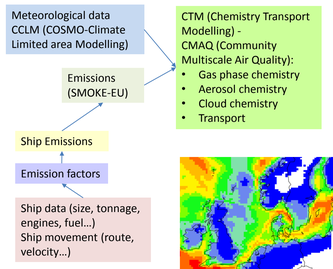
- Ion chromatography for anions (SO_4^{2-}, NO_3^-, Cl^-, S-compounds) and cations (NH_4^+, Na^+, K^+, Ca^{++}, Mg^{++})
- ICP-MS (Inductively Coupled Plasma Mass Spectrometry) for elemental analysis, especially V, Ni, Fe (as tracers for ship emission)
  Total Organic Carbon (TOC) and Elemental Carbon (EC)
- GC-MS (gas chromatography mass spectroscopy) for analyzing Polycyclic Aromatic Hydrocarbons (PAHs)

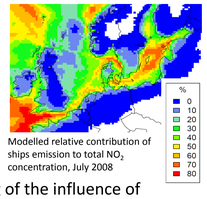
Passive (diffusive) sampling of SO_2 and NO_2 (IVL, passam)

- A cheap and easy-to-handle method for long-term air quality control (monthly) with adsorbers at remote platforms, but
- few information about sampled air history

Picture: LANUV NRW

Modelling



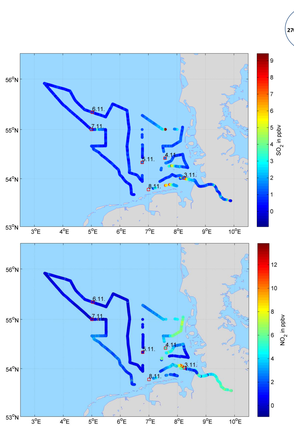


Modelled relative contribution of ships emission to total NO_2 concentration, July 2008

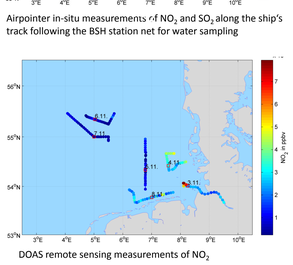
- Regional modelling of the influence of emissions from ships during different seasons
- Prediction of the influence of political measures regulating and controlling shipping emissions

5. Preliminary results

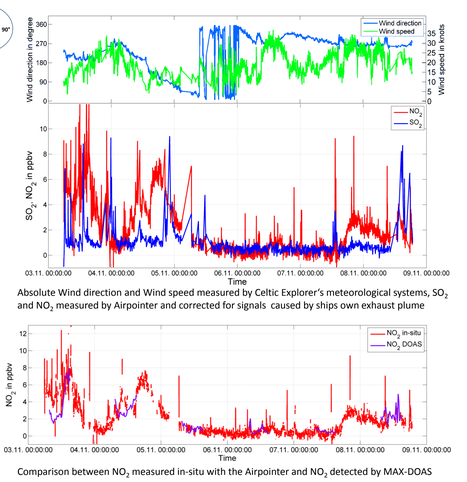
Test cruise on the RV Celtic Explorer from 3rd to 9th of November 2012:



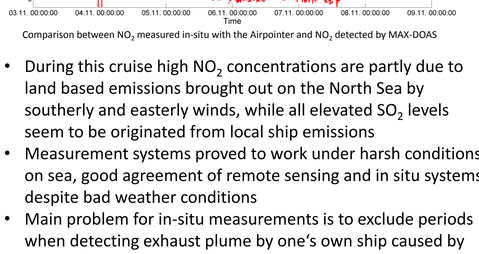
Airpointer in-situ measurements of NO_2 and SO_2 along the ship's track following the BSH station net for water sampling



DOAS remote sensing measurements of NO_2



Absolute Wind direction and Wind speed measured by Celtic Explorer's meteorological systems, SO_2 and NO_2 measured by Airpointer and corrected for signals caused by ships own exhaust plume

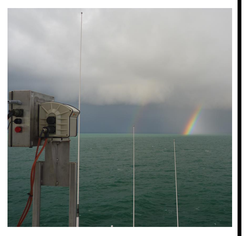


Comparison between NO_2 measured in-situ with the Airpointer and NO_2 detected by MAX-DOAS

- During this cruise high NO_2 concentrations are partly due to land based emissions brought out on the North Sea by southerly and easterly winds, while all elevated SO_2 levels seem to be originated from local ship emissions
- Measurement systems proved to work under harsh conditions on sea, good agreement of remote sensing and in situ systems despite bad weather conditions
- Main problem for in-situ measurements is to exclude periods when detecting exhaust plume by one's own ship caused by tailwind
- The late season (low sun) causes the data gaps in the MAX-DOAS time series

6. Outlook

- Taking part in further research ship cruises as well as establishing a stationary platform to achieve a long-term dataset with a high spatial resolution and a good coverage of potential seasonal effects
- Establishing methods to routinely analyze filter samples providing information on chemical transformation and deposition of pollutants as well as possible source „fingerprints"
- Using aircraft measurements of directly emitted exhaust plumes to have further information on the distribution of ship emissions
- Validation and improvement of existing chemical and transport models
- Improvement of instruments for prediction and control of ship emissions



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Selected references

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